(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 467 659 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
06.03.1996 Bulletin 1996/10

(51) Int Cl.6: G02F 1/1335, G02F 1/1343

(21) Application number: 91306487.9

(22) Date of filing: 17.07.1991

(54) A reflective-type liquid crystal display device and method for producing same

Reflektive Flüssigkristall-Anzeigevorrichtung und Verfahren zu seiner Herstellung

Dispositif d'affichage à cristal liquide du type réflectif et son procédé de fabrication

(84) Designated Contracting States:
DE FR GB NL

(30) Priority: 17.07.1990 JP 188775/90

(43) Date of publication of application:
22.01.1992 Bulletin 1992/04

(73) Proprietor: SHARP KABUSHIKI KAISHA
Osaka 545 (JP)

(72) Inventors:
- Mitsui, Seiichi
  Nara-shi, Nara-ken (JP)
- Kimura, Naofumi
  Nara-shi, Nara-ken (JP)
- Ishii Yutaka
  Nara-shi, Nara-ken (JP)

(74) Representative: Brown, Kenneth Richard et al
R.G.C. Jenkins & Co.
26 Caxton Street
London SW1H 0RJ (GB)

(56) References cited:
EP-A- 0 084 930
EP-A- 0 317 910
US-A- 4 239 346

- PATENT ABSTRACTS OF JAPAN vol. 11, no. 299 (P-621)(2746) 29 September 1987 & JP-A-62 091 918

EP 0 467 659 B1

Printed by Jouve, 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to a reflective-type liquid crystal display panel without back-light, and a method for producing same.

2. Description of the Prior Art:

The recent rapid development of liquid crystal display panels has paved the way to applications in many fields such as word processors, lap-top personal computers, and portable televisions. A special attention is being paid to a reflective-type liquid crystal display device without backlight, because the display device without backlight is lightweight, thin, and consumes less power.

In conventional reflective-type liquid crystal display panels a TN (twisted nematic mode) or a STN (super-twisted nematic mode) are used. In these modes a linear polarizer is necessarily used, but under the polarizer, half of the natural light is wasted in the display. Thus, even if an intensified natural light is used, the image display tends to be dark.

In order to solve this problem, a special mode is proposed for fully utilizing the natural light. For example, a cholesteric-nematic phase-change type guest-host mode is proposed by D. L. White and G. N. Taylor ("J. Appl. Phys." 45, Page 4718, 1974). In this guest-host mode, a cholesteric liquid crystal, which is a host liquid crystal, tends to change to a nematic phase under its own electric field. A reflective-type multicolor display device is also proposed, which is a phase change type guest-host system equipped with a mirco color filter ("Proceedings of the SID", vol. 29, page 157, 1988).

In order to display a brighter image in the mode in which no polarizer is needed, it is essential to intensify the light which tends to scatter perpendicularly to the screen. To achieve this, it is essential to control the surface roughness of the reflection plate. The second-mentioned literature teaches that the surface of a glass substrate is roughened by abrasives and then the roughened surface is etched with hydrofluoric acid for a controlled period of time, thereby securing an adequately flattened surface. The flattened surface is covered with a metal thin layer such as an Ag layer.

However, the problems are that the reflective surface of the glass substrate must be first roughened by abrasives, thereby making it difficult to secure a uniform surface of the substrate. In addition, such rugged surfaces makes it difficult to reproduce the same pattern.

The document EP-A-0 084 930 discloses a reflective type liquid crystal display device having a substrate coated with a polymer resin on which a reflective metal film is deposited. The surface of the polymer resin has a curved surface formed by photolithographic processes.

According to the present invention, there is provided a method of producing a reflection plate for a reflective-type liquid crystal display device, including preparing a glass substrate; characterised by growing an oxide layer on a surface of the glass substrate, etching the oxide layer on the glass substrate so as to make said surface of the glass substrate uneven, and forming a thin metal layer on the surface to form said reflection plate.

In a preferred embodiment, the uneven surface of the substrate comprises a repetition of hills and valleys, the hills being arranged at not larger than 100 μm.

In a preferred embodiment, the surface on which the metal thin layer is formed is disposed toward the liquid crystal layer.

In a preferred embodiment, the metal thin layer functions as a counter electrode for the pixel electrodes with the liquid crystal layer being interposed.

Thus, the invention described herein makes possible the objectives of (1) providing a reflective-type liquid crystal display panel capable of improved optical characteristics, and (2) providing a reflective-type liquid display capable of economy in production.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention may be better understood and their numerous advantages will become apparent to those skilled in the art by reference to the accompanying drawings as follows:

Figures 1a to 1d are diagrammatic views showing the process of fabricating a reflection plate according to an embodiment of the present invention;

Figure 2 is a diagrammatic view exemplifying a method for measuring the reflex characteristics of a reflection plate;

Figure 3 is a view showing reflective characteristics of the reflection plate produced by the process shown in Figures 1a to 1d;

Figures 4a to 4d are diagrammatic views showing the process of fabricating a reflection plate according to another embodiment of the present invention;

Figure 5 is a view showing the reflective characteristics of the reflection plate produced by the process shown in Figures 4a to 4d;

Figure 6 is a cross-sectional view showing a reflection plate display using the reflection plate produced by the process of Figures 4a to 4d;

Figure 7 is a graph showing the relationship between applied voltage and reflectivity in the reflection plate display device; and

Figure 8 is a cross-sectional view showing a reflective-type color liquid crystal display device modified by adding a color filter to the reflection plate display of Figure 6.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figures 1a to 1d, a process for fabricating a reflection plate used in a reflective-type liquid crystal display device will be described:

As shown in Figure 1a, a glass substrate 11 (manufactured by Corning, Item No. 7059) having a thickness of 1.1 mm is prepared, and an oxide is grown on one surface of the substrate 11 by sputtering so as to form an oxide layer 12 (Figure 1b). Oxides can be SiO_2, Al_2O_3, ZrO_2, SiO, TiO_2, SnO_2, ITO (indium tin oxide). The thickness of the oxide layer is preferably in the range of 0.01 to 1.0 μm. In the illustrated example, SiO_2 was used and grown to a thickness of 0.1 μm.

A liquid mixture of 25°C of one part of 47% hydrofluoric acid and 100 parts of 60% nitric acid at the ratio of 1 to 100 by weight was prepared. A glass substrate on which an oxide layer 12 was grown was submerged in the liquid mixture for 10 minutes to form an uneven surface 13 on the top surface of the substrate 11. In this specification, the "top" and "bottom" are relative words; in the drawing, the upper surface is called "top surface" and the lower surface "bottom".

The uneven surface 13 includes a plurality of grooves which consist of hills and valleys alternately repeated. The hills are 0.8 μm on average, arranged at average pitches of 5 μm. The pitch means a mean distance between adjacent hills. The bottom surface 10 of the substrate 11 is evenly etched to form no uneven surface and maintains transparent. It is not necessary to cover the bottom surface with a resist or the like.

The uneven surface 13 of the substrate 11 is covered with a metal thin layer 14 (Figure 1d). The metal thin layer 14 can be made of Al, Ni, Cr or Ag. The thickness of the metal thin layer 14 is preferably in the range of 0.01 to 1.0 μm. In this example, Ag was deposited to form the metal thin layer 14 by a vapor deposition method. In this way a reflection plate was obtained.

The reflection characteristics are measured by the following manner:

When a reflection plate 15 is used in a liquid crystal display device, a surface of the reflection plate keeps contact with the liquid crystal layer. It is preferable to measure the reflective characteristics of the reflection plate as it keeps contact with the liquid crystal layer. A liquid crystal layer and a reflection plate have the same refractive index, that is, about 1.5. As a result, when the reflective characteristics is measured from the bottom surface 10 of the reflection plate 15, no difference occurs in the measuring result from when they are measured through the interface between the top surface of the reflection plate 15 and the liquid crystal layer 21. In this example, the reflection characteristics were measured from the bottom surface 10 of the glass substrate 11.

As shown in Figure 2, the reflection characteristics is measured by measuring the scattering light from an incident light to the reflection plate 15 by means of a photomultimeter 5. The incident light 3 is projected on the bottom surface 10 at an angle θ to a normal 2. The photomultimeter 5 is fixed on the normal 2 passing through a point at which the light is projected on the reflection plate 15.

In Figure 3, the reflective intensity of the light incident to the normal 2 at an angle θ is expressed in terms of a distance from the origin 0 in the direction of θ. The circle 32 depicted in dotted lines was obtained when a reflection plate of magnesium oxide was used. The curve 35 of the reflection characteristics is similar to the circle 32, which indicates that the reflection plate 15 has similar reflection characteristics to those of the reference white plate (the magnesium oxide plate). The display device incorporating the reflection plate 15 of this example displayed a bright image.

In the illustrated example, the average pitch between one hill and the next was 5 μm, but up to the pitches of 100 μm, it was found that the same results as in the illustrated example were obtained. If the hills are formed with an average pitch of larger than 100 μm, the incident light to the reflection plate cannot be scattered in all directions.

Referring to Figure 4, a modified process will be described:

As shown in Figure 4a, a glass substrate (manufactured by Corning, Item No. 7059) having a thickness of 1.1 mm was prepared, and an ITO layer was deposited to a thickness of 0.1 μm by sputtering to form an oxide layer 42 (Figure 4b).

Oxides can be SiO_2, Al_2O_3, ZrO_2, SiO, TiO_2, SnO_2, ITO (indium tin oxide). The thickness of the oxide layer is preferably in the range of 0.01 to 1.0 μm.

A liquid mixture of 25°C of one part of 47% hydrofluoric acid and 100 parts of 60% nitric acid at the ratio of 1 to 100 by weight was prepared. A glass substrate on which an oxide layer 42 was grown on the glass substrate 11. The glass substrate 11 was submerged in the liquid mixture for 10 minutes to form an uneven surface 43 on the top surface of the substrate 11 (Figure 4c). In this way the substrate 11 is provided with an uneven surface 43 on one side.

The uneven surface 43 includes a plurality of grooves which consist of hills and valleys alternately repeated. The hills are 0.5 μm with average pitches of 5 μm. The uneven surface **43** is covered with a metal thin layer **44** by a vacuum method (Figure 4d). In this way a reflection plate **45** was obtained.

The etching was continued for 12 minutes to form a reflection plate **46**. This reflection plate **46** also includes hills and valleys alternately arranged wherein the hills were 0.8 μm high, and the average pitches were 5 μm on average.

Figure 5 shows the curves **55** and **56** of reflection characteristics of the reflection plates **45** and **46**. The reflection characteristics were measured by the same manner as described above with respect to Figure 2. The reflection plate **45** has a small reflectivity toward the normal to the reflection plate **55** when the incidence angle θ is small, whereas, when the incidence angle θ is large, the reflectivity toward the normal is large. In contrast, it will be understood that the reflection plate **46** had the same reflection characteristics as those of the reference white plate (the magnesium oxide plate). In this way, by controlling a period of etching the reflectivity toward the normal can be increased as in the reflection plate **45**, and the incidence light can be scattered in all directions as in the reflection plate **46**.

Figure 6 shows a cross-section of a reflective-type liquid crystal display device using the reflection plate **45**. The device includes an active matrix substrate **20** and the reflection plate **45**. The active matrix substrate **20** includes a transparent plate **23** such as glass, thin film transistors (TFT) **24** formed on the substrate **20**, and pixel electrodes **25** connected to the TFTs **24**. The pixel electrodes **25** and the TFT **24** are covered with an alignment layer **26**. The reflection plate **45** is covered with another alignment layer **27**. A metal thin layer **44** of the reflection plate **45** functions as a counter electrode for the pixel electrodes **25** with a liquid crystal layer being interposed therebetween.

The reference numeral **22** denotes a liquid crystal confining layer between the active matrix substrate **20** and the reflection plate **45**. For example, the liquid crystal confining layer **22** can be made by screen printing in an adhesive sealing agent containing spacers of 7 μm. After the liquid crystal confining layer **22** is formed, it is evacuated to produce a vacuum inside. Then, liquid crystal is confined in the layer **22**. In the illustrated embodiment, a guest-host liquid crystal (manufactured by E. Merck) with 5% chiral material (manufactured by E. Merck) was confined in the layer **22** as the liquid crystal layer **21**.

Figure 7 shows the relationship between voltage and reflection characteristics of the finished reflective liquid crystal display device. The reflectivity was measured with the reflective liquid crystal display device placed at the position where the reflection plate **15** was placed in Figure 2. The vertical axis indicates the resistivity, and the horizontal axis indicates the applied voltage between the pixel electrode **25** and the metal thin layer **44** (counter electrode). The resistivity of a light incident at an angle of 30° was measured by obtaining the ratio of the intensities of light diffusion along the respective normals to the reference white plate and the display device. As shown in Figure 7, the reflectivity when the voltage was applied was 50%, and the ratio of contrast was 27.

In the illustrated embodiment, as the surface on which the metal thin layer **44** covering the reflection plate **45** is positioned toward the liquid crystal layer **21**, no parallax is caused, thereby securing a satisfactory image representation. In addition, the metal thin layer **44** functions as a counter electrode, thereby eliminating the necessity of forming an extra counter electrode. Thus, the manufacturing process is simplified.

In addition, as shown in Figure 8, the color filter **28** is provided in each pixel electrode **25**, and a black mask **29** is provided between the adjacent color filters **28**. In this way the reflective-type liquid crystal display panel of the present invention can be easily adapted into a reflective-type color liquid crystal display device.

In the illustrated embodiment, the metal thin layer **44** is formed after the oxide layers **12** and **42** are formed on the substrate **11** but it is possible to abrade the substrate **11** on which an oxide film is formed, and after etching the abraded surface, to form the metal thin layer **44**. Alternatively, it is possible to form an oxide film on the glass substrate **11** after it is abraded.

It is understood that various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope of this invention.

Claims

1. A method of producing a reflection plate (15; 45; 46) for a reflective-type liquid crystal display device, including preparing a glass substrate (11);

   characterised by growing an oxide layer (12; 42) on a surface of the glass substrate, etching the oxide layer on the glass substrate so as to make said surface (13; 43) of the glass substrate uneven, and forming a thin metal layer (14; 44) on the surface (13; 43) to form said reflection plate.

2. A method as claimed in claim 1, wherein the oxide layer (12; 42) is formed by sputtering.

3. A method as claimed in any preceding claim, wherein the uneven surface (13; 43) of the substrate (11) comprises a repetition of hills and valleys, the hills being arranged with a pitch not larger than 100 μm.

4. A method of producing a reflective-type liquid crystal display device comprising:

   forming a reflection plate (15; 45; 46) by the method as claimed in any preceding claim, and interposing a liquid crystal layer (21) between the reflection plate and a transmissive substrate (20) including pixel electrodes (25).

5. A method as claimed in claim 4, wherein said surface (13; 43) on which the thin metal layer (14; 44) is formed is disposed toward the liquid crystal layer (21).

6. A method as claimed in claim 5, further comprising connecting the thin metal layer (14; 44) as a counter

electrode for the pixel electrodes (25).

Patentansprüche

1. Verfahren zum Herstellen einer Reflexionsplatte (15; 45; 46) für eine reflektierende Flüssigkristall-Anzeigevorrichtung, bei dem ein Glassubstrat (11) bereitgestellt wird; **gekennzeichnet durch** das Aufwachsen einer Oxidschicht (12; 42) auf eine Oberfläche des Glassubstrats, ein Ätzen der Oxidschicht auf dem Glassubstrat, um diese Fläche (13; 43) des Glassubstrats uneben zu machen, und ein Herstellen einer dünnen Metallschicht (14; 44) auf der Fläche (13; 43) um die Reflexionsplatte herzustellen.

2. Verfahren nach Anspruch 1, bei dem die Oxidschicht (12; 42) durch Sputtern hergestellt wird.

3. Verfahren nach einem der vorstehenden Ansprüche, bei dem die unebene Fläche (13; 43) des Substrats (11) eine Wiederholung von Hügeln und Tälern aufweist, wobei die Hügel mit einer Schrittweite nicht über 100 µm angeordnet sind.

4. Verfahren zum Herstellen einer reflektierenden Flüssigkristall-Anzeigevorrichtung, bei dem eine Reflexionsplatte (15; 45; 46) durch das Verfahren nach einem der vorstehenden Ansprüche hergestellt wird und eine Flüssigkristallschicht (21) zwischen der Reflexionsplatte und einem Pixelelektroden (25) aufweisenden lichtdurchlässigen Substrat (20) eingefügt wird.

5. Verfahren nach Anspruch 4, bei dem die Fläche (13; 43), auf der die dünne Metallschicht (14; 44) hergestellt wird, zur Flüssigkristallschicht (21) hin angeordnet wird.

6. Verfahren nach Anspruch 5, bei dem ferner die dünne Metallschicht (14; 44) als Gegenelektrode für die Pixelelektroden (25) angeschlossen wird.

Revendications

1. Procédé de production d'une plaque réfléchissante (15; 45; 46) pour un dispositif d'affichage à cristal liquide de type réfléchissant, consistant à préparer un substrat de verre (11),

   caractérisé en ce que l'on fait croître une couche d'oxyde (12; 42) sur une surface du substrat de verre, on attaque la couche d'oxyde sur le substrat de verre de manière à rendre ladite surface (13; 43) du substrat de verre inégale et on forme une couche de métal mince (14; 44) sur la surface (13; 43) pour former ladite plaque réfléchissante.

2. Procédé selon la revendication 1, dans lequel la couche d'oxyde (12; 42) est formée par pulvérisation cathodique.

3. Procédé selon l'une quelconque des revendications précédentes, dans lequel la surface inégale (13; 43) du substrat (11) comprend une répétition de collines et de vallées, les collines étant agencées avec un pas qui n'est pas supérieur à 100 µm.

4. Procédé de production d'un dispositif d'affichage à cristal liquide de type réfléchissant comprenant :

   la formation d'une plaque réfléchissante (15; 45; 46) par le procédé selon l'une quelconque des-revendications précédentes et l'interposition d'une couche de cristal liquide (21) entre la plaque réfléchissante et un substrat de transmission (20) comprenant des électrodes de pixels (25).

5. Procédé selon la revendication 4, dans lequel ladite surface (13; 43) sur laquelle la mince couche métallique (14; 44) est formée est disposée vers la couche de cristal liquide (21).

6. Procédé selon la revendication 5, comprenant en outre la connection de la mince couche métallique (14; 44) en tant que contre-électrode pour les électrodes de pixels (25).

Fig. 1 a

Fig. 1 b

Fig. 1 c

Fig. 1 d

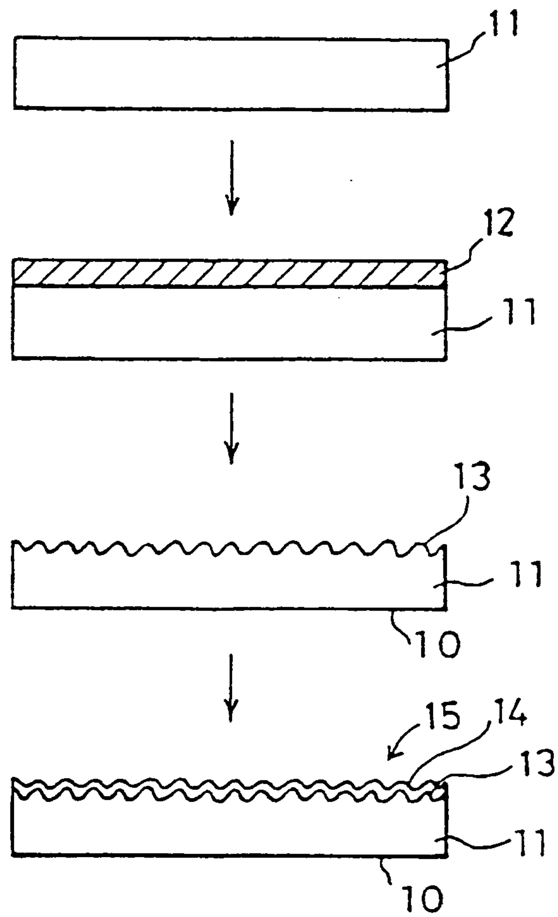


Fig. 2

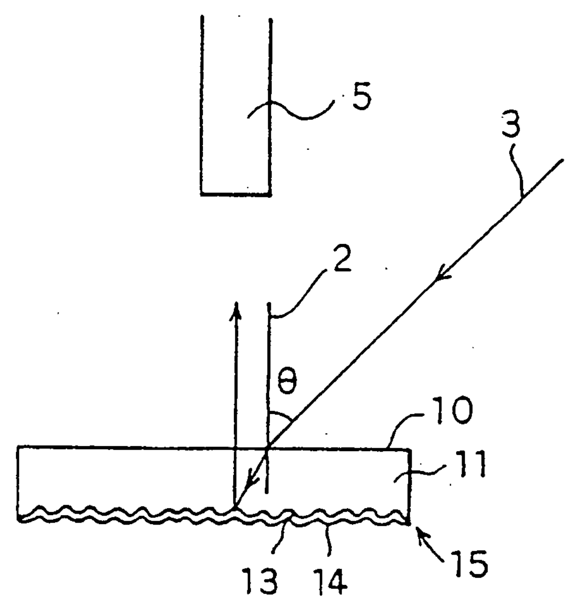


Fig. 6

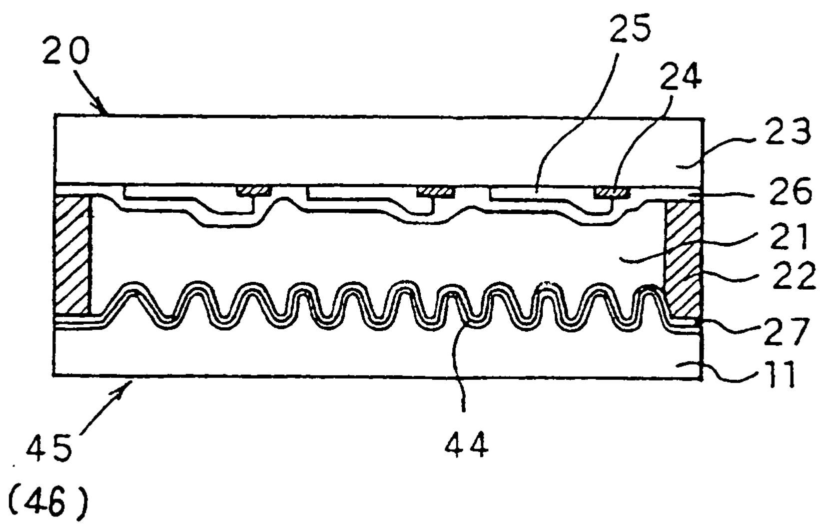


Fig. 3

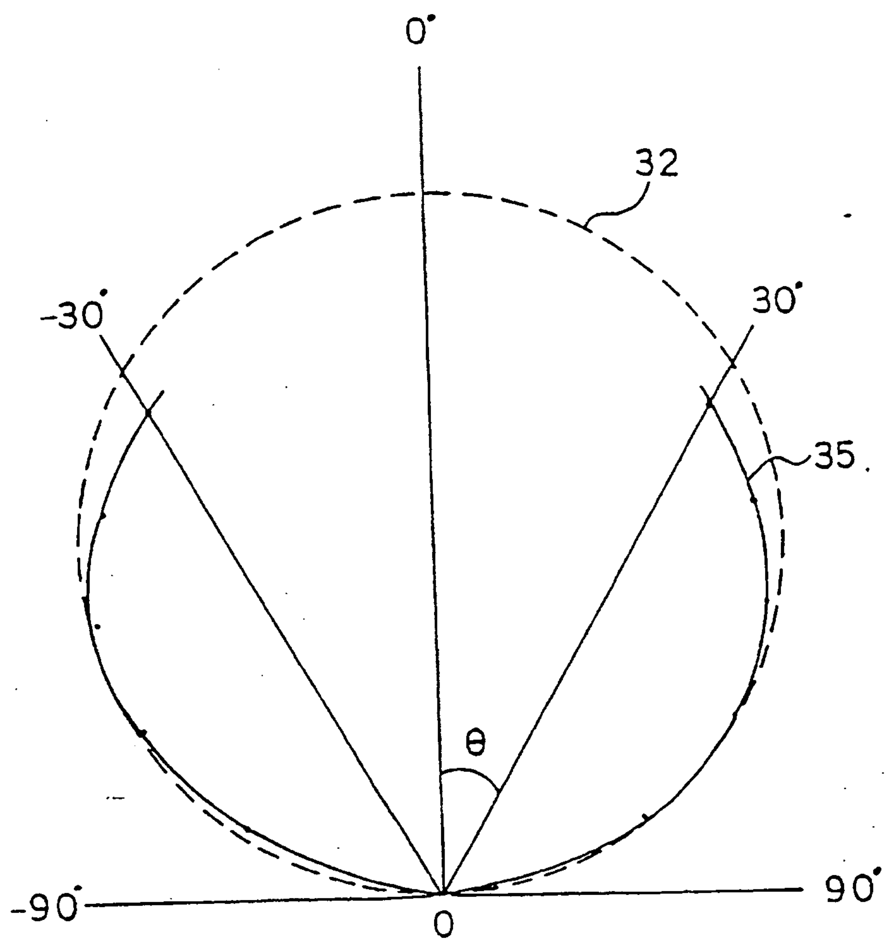


Fig.4 a

Fig. 4 b

Fig. 4 c

Fig.4 d

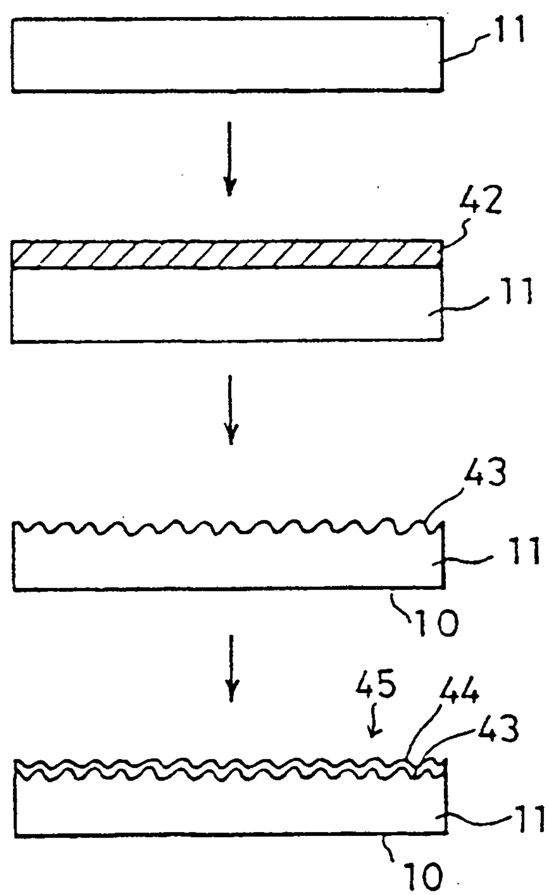


Fig. 5

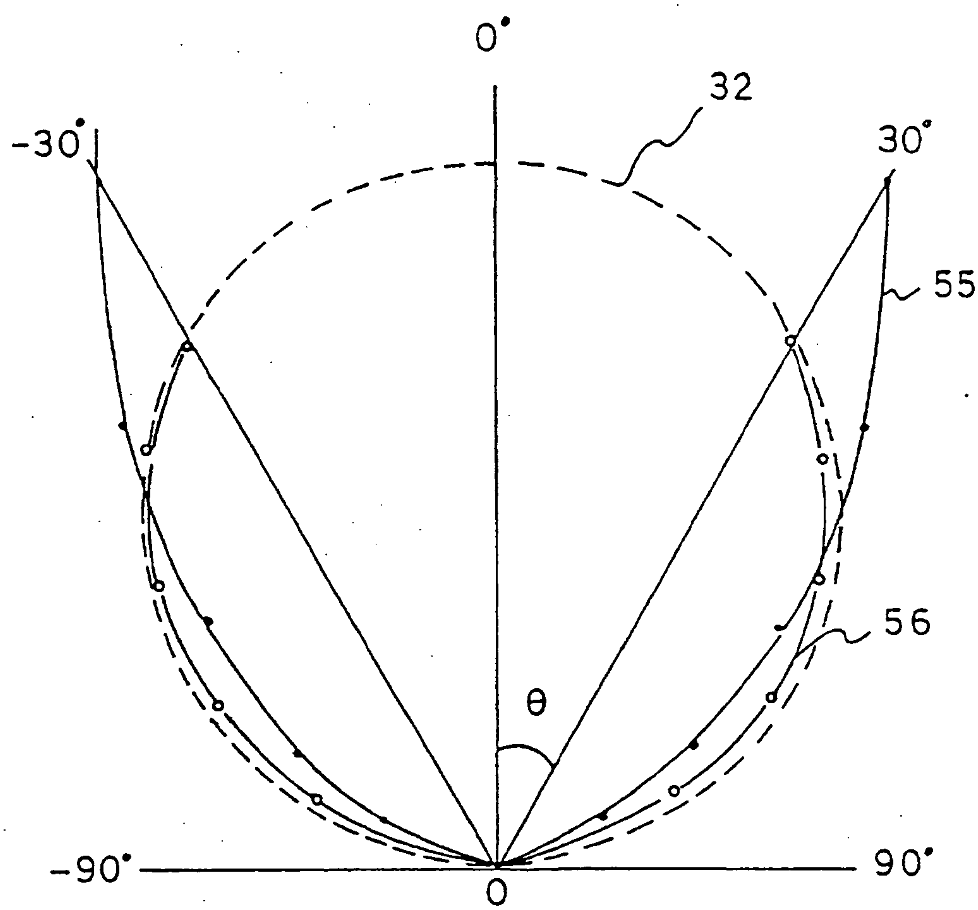


Fig. 7

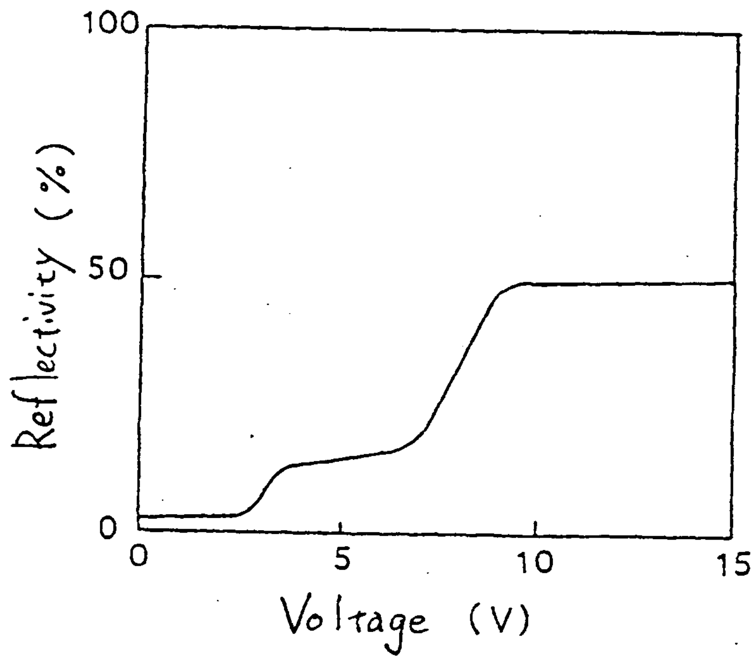
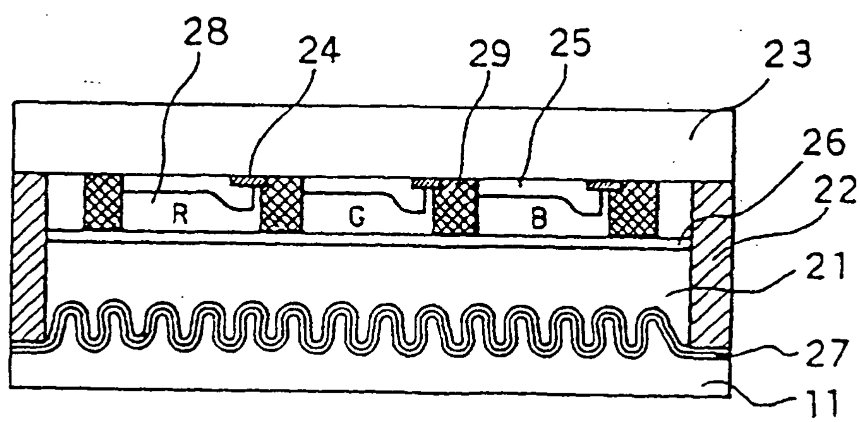

100
50
0
Reflectivity (%)
0
5
10
15
Voltage (V)

Fig. 8


28
24
29
25
23
26
22
21
27
11
R
G
B